STORMWATER PONDS IN COASTAL SOUTH CAROLINA

2018 State of Knowledge Report
Executive Summary

S.C. SEA GRANT CONSORTIUM
Coastal Science Serving South Carolina

STORMWATER PONDS RESEARCH AND MANAGEMENT COLLABORATIVE

The S.C. Sea Grant Consortium established the South Carolina Stormwater Ponds Research and Management Collaborative in 2014 to address the pressures on the state's communities, infrastructure, and natural and human resources from the increasing use of ponds for stormwater management. Stormwater ponds, especially detention ponds, are by far the most common best management practice (BMP) for controlling stormwater runoff from developed landscapes in coastal South Carolina.

The Collaborative engages technical and management expertise from throughout the state to (1) develop an integrated, sustainable, economic and natural resource strategy for the construction, use, and maintenance of stormwater ponds serving existing and future South Carolina communities; (2) satisfy the information needs and concerns of existing local communities, homeowners associations (HOAs), businesses, and industries surrounding stormwater pond design, ecology, efficiency, effectiveness, and management; (3) characterize coastal stormwater ponds to understand their functionality, durability, benefits, and costs; and (4) ultimately develop new and innovative engineering and construction practices to ensure that current and future stormwater ponds function without concerns about possible ecological impacts or additional economic costs associated with their management and maintenance.

For more information or to receive a copy of the full State of Knowledge report when it is available, please contact the South Carolina Sea Grant Consortium at (843) 953-2078, or email info@scseagrant.org.

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INTRODUCTION

The state of South Carolina (S.C.) has seen some of the most rapid coastal population growth rates and overall rates of urbanization in the nation. Its upward trend in population growth is expected to continue with a projected population in the coastal zone of over 1.5 million by the year 2030. The resulting urban and suburban growth in the region increases the amount of impervious surfaces (e.g., roofs, roads, parking lots) to support the associated development. As impervious surface area in a watershed increases so does the amount of stormwater runoff. In coastal S.C., the most common best management practice (BMP) to control runoff is stormwater ponds (herein, "ponds").

Through working with our stakeholders, the S.C. Sea Grant Consortium (Consortium) identified ponds as a growing topic of concern throughout our eight coastal counties (**Fig. ES.1**). In October 2014, the Consortium initiated the Stormwater Ponds Research and Management Collaborative, an effort that gathered scientists and resource managers to investigate and address the challenges associated with these systems. The long-term vision of the Collaborative is to develop integrated, sustainable strategies for the

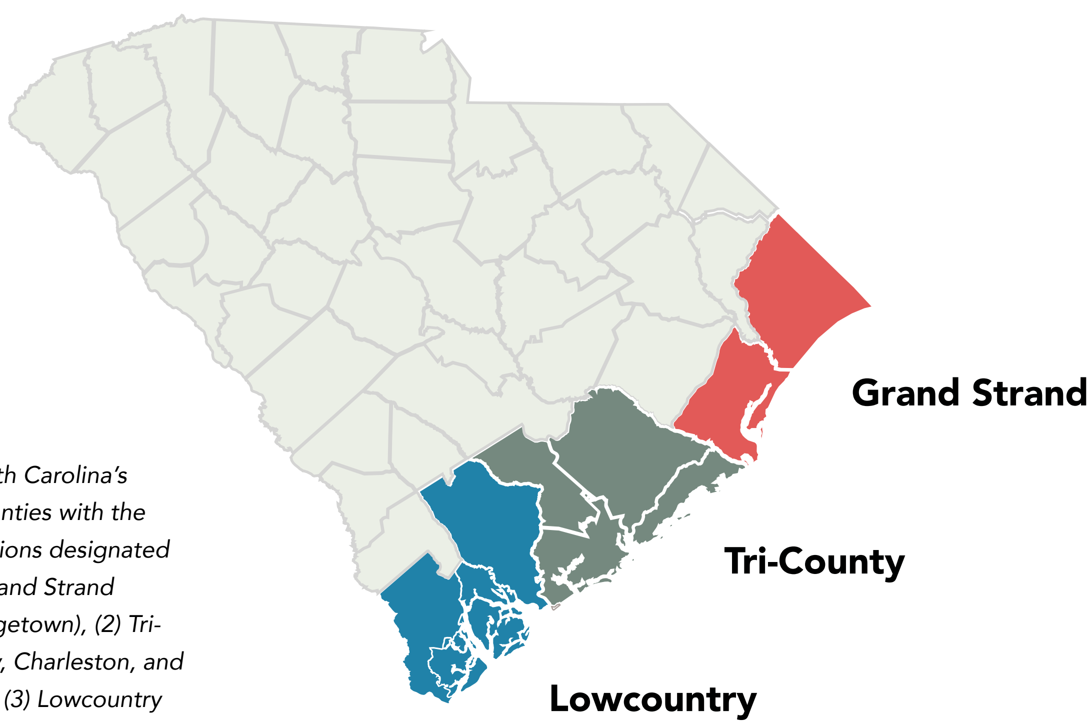

Figure ES.1 *South Carolina's eight coastal counties with the three coastal regions designated as follows: (1) Grand Strand (Horry and Georgetown), (2) Tri-County (Berkeley, Charleston, and Dorchester), and (3) Lowcountry (Colleton, Beaufort, and Jasper).*

construction and use of ponds tailored to the specific climate, hydrology, geography, and cultural needs of the coast.

What follows is a scientific state-of-knowledge report on ponds in coastal South Carolina. This effort consists of an inventory of existing ponds, a comprehensive literature review, gap analysis, and recommendations for outreach. Twenty-two researchers from six state institutions were involved in the project, which was funded by the State of South Carolina and National Sea Grant College Program from 2014 to 2016.

Each project team worked to ensure that any information on ponds from coastal S.C. was included in the report. When coast-specific or S.C.-specific data were lacking on a given topic, studies from other regions or states were incorporated, as appropriate.

To satisfy the informational needs of our diverse stakeholder groups, we produced a series of products to convey the information gathered by our project teams. This technical report was written for the following audiences: researchers, the stormwater management community, and local and state decision-makers. To share this report with non-technical groups, specifically individual property owners and homeowners associations (HOAs), the Consortium created a pamphlet and booklet series written for general audiences.

A goal of the Consortium is to ensure that science works for S.C.'s coastal communities. We believe that cultivating a science-based understanding of the engineered purpose and current conditions of our coastal ponds among diverse groups of stakeholders is vital for facilitating future collaborations. Ultimately, these partnerships will produce new and innovative practices to ensure effective, long-term stormwater management along our coast. Finally, our vision for this ongoing effort is to have cleaner, healthier, and more economically viable coastal ecosystems.

The topics covered in the report include:

Inventory and classification of stormwater ponds, as of 2013, in the coastal counties.

Transport of stormwater over surfaces and the function of ponds to retain runoff.

Nature of **pollutants** in stormwater and the storage ability of ponds.

Ecological function of stormwater ponds within the coastal landscape.

Policy and regulatory lens of coastal stormwater management.

Economic assessment of stormwater management.

Development of a **communications strategy** towards improved stormwater pond awareness and maintenance.

REPORT HIGHLIGHTS

Pond Landscape (Chapter 1)

Erik M. Smith[1,2], Denise M. Sanger[3,4], Andrew Tweel[3], Erin Koch[3]

NUMBER: Based on 2013 aerial imagery, there are 21,594 ponds in the coastal zone associated with either rural or development-related land uses (**Fig. ES.2**).

SIZE: The median size of all ponds is 0.47 acres, while development-related ponds are 0.54 acres. The vast majority (98 percent) of all ponds are less than 10 acres. However, because of this extreme skewness the combined area of large ponds is 32 percent of cumulative pond area.

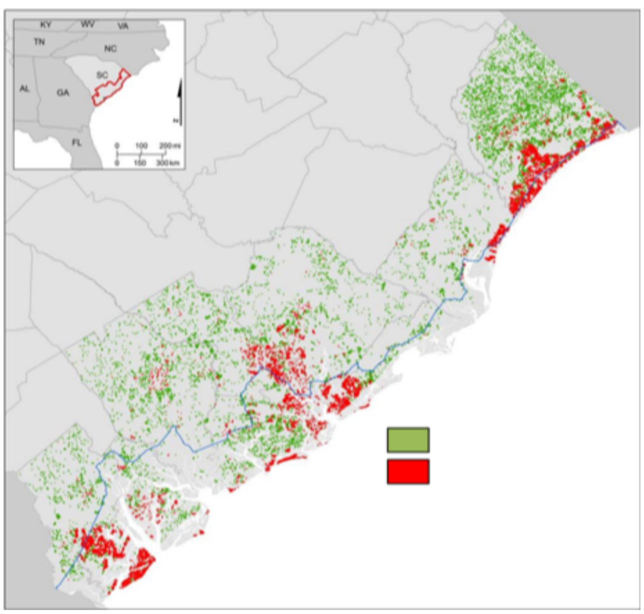

Figure ES.2 *Ponds color-coded as either non-development (green) or development-related (red) land uses. Blue line denotes the upstream limit of the DHEC-OCRM Critical Area.*

LAND-USE: Developed ponds, those associated with golf, residential, or commercial development constitute 43 percent of total ponds inventoried.

PROXIMITY: The majority of all ponds are within one mile of major downstream receiving water bodies.

DISTRIBUTION: Horry, Charleston, and Beaufort counties have the greatest number of stormwater ponds: 64 percent of total.

COVERAGE: Total area covered by ponds in the Grand Strand and Charleston County has increased by 4 percent per year (1994 to 2013); more rapidly than overall development (**Fig. ES.3**)

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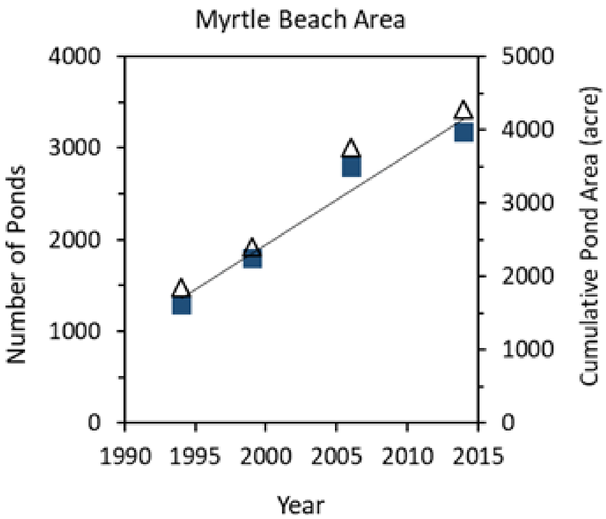

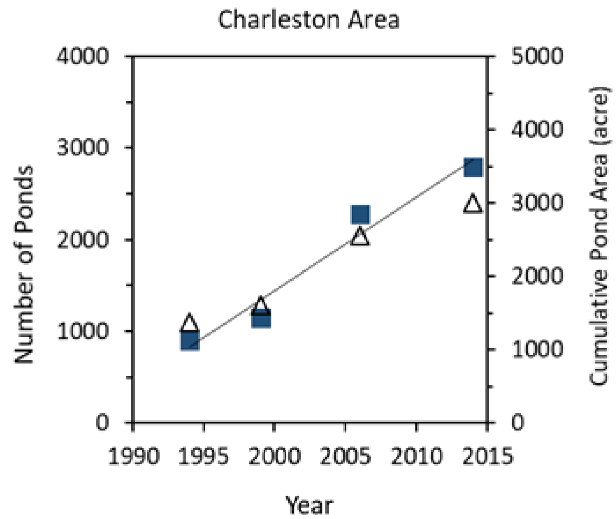

Figure ES.3 *Change over time in pond number (squares) and cumulative surface area (triangles) of development-related ponds for the greater Myrtle Beach area and the greater Charleston area.*

Transport and Fate of Contaminants in Stormwater (Chapter 2)

Vijay M. Vulava[1], Barbara A. Beckingham[1], and Timothy J. Callahan[1]

Stormwater runoff is a major problem associated with increased development. Impervious surfaces prevent rainfall from being observed naturally, causing up to a 45 percent increase in surface runoff (**Fig. ES.4**). As stormwater flows over the ground it acquires and transports pollutants. Because stormwater is not treated, what flows into storm drains later ends up in receiving waterbodies, becoming the leading cause of poor water quality.

HYDROLOGY: Water flow in coastal S.C. is strongly influenced by the flat topography, shallow water table, and especially for the Low-country region, tidal exchange.

BEST MANAGEMENT PRACTICES (BMPs): Wet detention ponds that maintain a permanent pool of water are the most common stormwater BMP in coastal S.C.

POLLUTANT REMOVAL: Chemicals and pathogens in the environment that become adsorbed or attached to particles are stored by ponds via sedimentation; pollutants may be

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removed by biological processes. According to the International BMP Database, median pollutant removal rates for wet ponds range from 17 to 96 percent, depending on the pollutant type.

PARTICLES: The physical and chemical characteristics of particles including size, density, and organic content, impact their transport and fate. For example, small particles (< 300 μm diameter) are associated with high concentrations of contaminants but are more mobile, thus less likely to settle to pond bottoms.

RESIDENCE TIME: This is the most limiting factor to water quality improvement, as the time stormwater spends in a pond controls the degree of both sedimentation and transformation of pollutants.

NEW POND DESIGNS: Building ponds with a length to width ratio of at least 3:1, ensuring a large pond surface area relative to the drainage area, and maintaining a pond depth of at least 4 to 6 feet are good design options for improving the quality of water exiting a pond.

RETROFITS: Options that increase stormwater residence time, such as the installation of sluice gates at outflows and/or the addition of a littoral shelf or forebay, can improve an existing pond's effectiveness at pollutant removal.

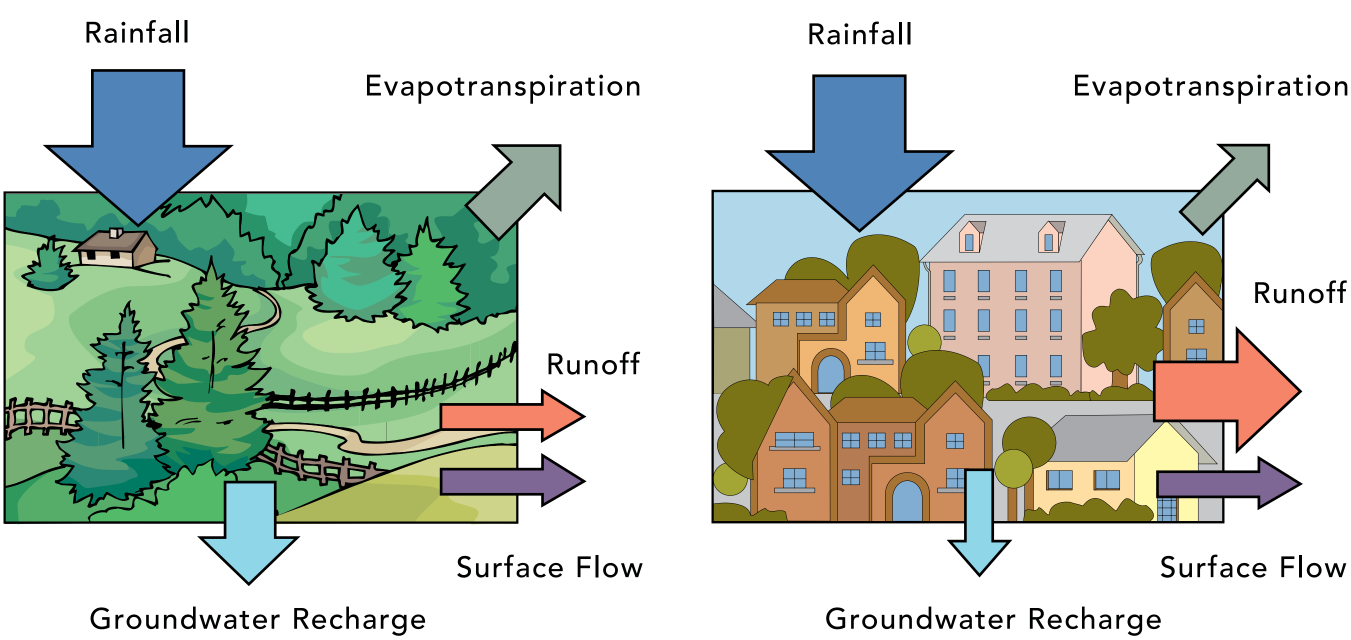

Figure ES.4 *Differences in water flows between natural (left) and developed (right) environments. Arrow width indicates the relative volume of each flow. The relative increase in runoff depends on the amount of impervious surface built.* Credit: S.C. Sea Grant Consortium, *Tidal Creek Habitats: Sentinels of Coastal Health.*

Nonpoint Source (NPS) Pollutants (Chapter 3)

Mohammed Baalousha[1], Samantha McNeal[1], and Geoffrey I. Scott[1]

Two-thirds of all pollutants impacting water quality are attributed to nonpoint source (NPS) contaminants such as metals, organics, microbes, and nutrients. These are derived from a variety of natural and anthropogenic activities, as shown in the diagram below (**Fig. ES.5**). Ponds can be highly efficient at removing pollutants, depending on pond geometry, depth, proximity to urban areas, and hydrology. However, this high pollutant loading and low water circulation can contribute to a number of water quality problems within pond basins. Due to settling of particle-bound pollutants, pond sediments can exhibit high concentrations of chemicals that could pose health risks to human, aquatic, and benthic life.

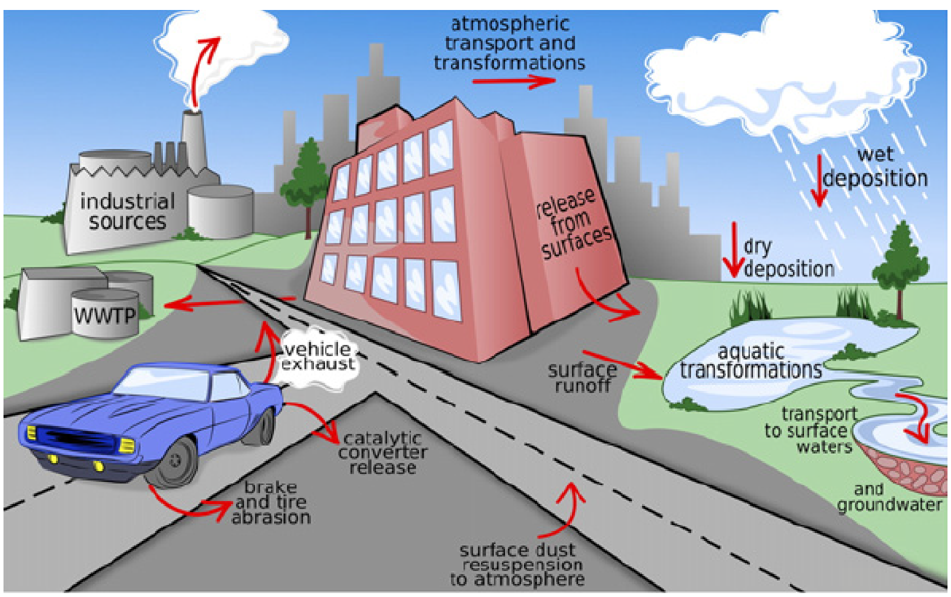

Figure ES.5 *Arrows indicate flows of nonpoint source pollutants from a variety of sources within the environment.* Credit: Baalousha et al. (2014) *Nanoscience and the Environment*, Elsevier.

HOT SPOTS: The concentrations of a variety of pollutants, including heavy metals (especially copper, chromium, and cadmium), polycyclic aromatic hydrocarbons (PAHs) that result from combustion reactions, and microbial pollutants are elevated in coastal S.C. pond sediments as compared to estuarine sites. Mixtures of chemical contaminants in sediments may also be toxic to benthic species.

CONTAMINANTS OF EMERGING CONCERN (CECs): These include pharmaceuticals, personal care products, and contemporary use pesticides (CUPs) that have the potential for negative effects on aquatic life. Nanomaterials

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(titanium, chromium, and iron) were found in several residential and golf course ponds. The CUP, chlorpyrifos, was found in 56 percent of S.C. ponds and is often associated with the herbicide atrazine, which is synergistically toxic to crustaceans.

MICROBIAL POLLUTANTS: Bacteria and viruses can be introduced to waterways via leaking septic systems, wildlife sources, and pet feces. Bacterial indicators were found to be lower in ponds than in runoff, and similar to concentrations in tidal creeks. Metals found in pond sediments have potential to induce antibiotic resistance in bacterial communities.

REMOVAL CAPABILITIES: Stormwater ponds in S.C. can substantially reduce microbial contaminants from runoff, largely via sedimentation. These removal efficiencies, or the percent of bacteria entering in runoff that is trapped by the pond, are highly variable.

POND DESIGNS FOR WATER QUALITY: Effective design options to protect downstream water quality include ensuring pond surface area is at least 5 percent of the surrounding impervious surface area, the inclusion of forebays or vegetated littoral shelves to trap sediments, and the construction of multi-pond series rather than stand-alone ponds.

Stormwater Pond Ecology (Chapter 4)

Dianne I. Greenfield[1,2], Erik M. Smith[1,3], Andrew W. Tweel[2], Denise M. Sanger [2,4], and Kimberly Sitta[5]

Stormwater ponds create unique ecosystems because they have reduced flushing capacity associated with high residence times, making them susceptible to stagnation. Furthermore, they accumulate nutrients from fertilizer runoff and are natural "incubators" for the proliferation of algal blooms. Ponds may also serve as valuable permanent and/or transient habitats for a range of species. Given the scarcity of natural open-canopy ponds or lakes in the Southeast coastal plain, these habitats are a direct result of development and have become integral features throughout S.C.'s coastal landscape.

FISH KILLS: Hypoxia (low dissolved oxygen)

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Figure ES.6 *A cyanobacteria bloom in a stormwater pond in coastal S.C. Some cyanobacteria can produce toxins, like microcystin, which may be toxic to aquatic life, wildlife, pets, and humans.* Credit: Dianne Greenfield

resulting from stagnation and decaying algal blooms result in about 68 percent of fish kills in ponds; harmful algal blooms (HABs) account for 27 percent, and these events can occur simultaneously.

NUTRIENTS: Pond biogeochemistry is highly complex, and growth of different algae are influenced by the relative concentration of nitrogen (N) to phosphorus (P). However, the cycling processes are more similar between fresh and saline systems than previously believed, as algae can be stimulated and/or co-limited by both N and P, whereas P was previously thought to ultimately control freshwater processes.

HABs: Elevated N, especially organic sources like urea, stimulates growth of bloom taxa like cyanobacteria (**Fig ES.6**) and dinoflagellates. Organic N is used in approximately half of commercially available fertilizers.

MICROBES: Fecal coliform and pathogenic *Vibrio* spp. can reach high concentrations in ponds; some bacteria in ponds, including those associated with pet waste, are resistant to antibiotics.

ANIMALS: Amphibians, like frogs, breed in ponds but can be disturbed by construction and are susceptible to toxins found in pond sediments. Ponds are common habitat for alligators and are often stocked with fish, including the economically-important American eel (*Anguilla rostrata*).

INVASIVE SPECIES: Ponds can host exotic species; 18 percent of coastal S.C. ponds surveyed by S.C. Department of Natural Resources were found to be infested with invasive apple snails.

CHANGE: Water temperature, salinity, connectivity, and rates of exchange are main factors regulating ponds, and the ranges of these parameters will likely change. Future climate scenarios favor accelerations of toxic algal bloom developments and increased frequency and duration of hypoxia.

Policy Lens of S.C. Stormwater Management (Chapter 5)

Lori A. Dickes[1], Jeffery Allen[2], Monika Jalowiecka[3], Katie Callahan[4], Bridget Cotti-Rausch[5]

Similar to many environmental issues, stormwater management operates within a network of layers of regulatory and policy oversight. The Environmental Protection Agency (EPA) defines a stormwater BMP as a "technique, measure, or structural control" that meets permitting requirements by managing the quantity and quality of runoff. In 2007, a review of 511 coastal ponds by S.C. Department of Health and Environmental Control (DHEC) found 15 percent were not in compliance with permitting requirements.

FEDERAL POLICY: Most broadly, stormwater falls under the Clean Water Act (CWA) enacted in 1972, a complex regulatory document governing water pollution control.

FEDERAL PERMITS: A key section of the CWA is the National Pollutant Discharge Elimination System (NPDES). This program requires counties and municipalities to obtain permits to monitor, reduce, and control pollutants found in stormwater.

STATE CONTROL: The federal government gives control to states to enact specific regulatory actions to meet federal permitting requirements. In S.C. this responsibility is held by the S.C. Department of Health and Environmental Control (DHEC).

MUNICIPAL SEPARATE STORM SEWER SYSTEMS (MS4s): The NPDES program divides permits into the following categories: regulated MS4s, construction, industrial, and general. In coastal S.C. there are currently 25 MS4-regulated communities. Developers report to the MS4 which then reports directly to DHEC; this process is the regulatory oversight for pond construction.

LOCAL OVERSIGHT: In MS4-permitted areas the county or city performs scheduled inspections on private pond systems to ensure all permitted BMPs are in compliance with the NPDES program as administered by DHEC. Though ponds are the most common BMPs, only a minority of surveyed stormwater

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professionals believe them to be the best tool for managing runoff (**Fig. ES.7**).

OLDER COMMUNITIES: Communities built prior to an area becoming designated as an MS4 do not have stormwater management plans and are not inspected by the municipality. However, they are required to maintain all BMPs in a "functional condition."

COASTAL ZONE: In the coastal counties, additional regulatory requirements falling under the S.C. Coastal Zone Management Program must be met to protect our vital coastal habitats.

Ponds are the best tool for stormwater management.

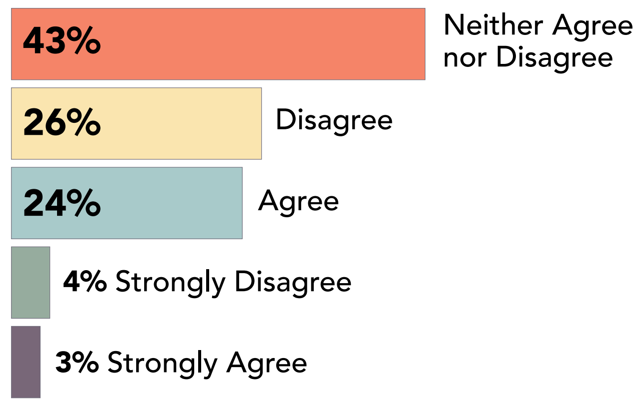

Figure ES.7 *A survey of stormwater professionals from coastal S.C. cities, towns, and counties designated as MS4s found that only 24 percent believe ponds to be the best tool for stormwater management. Additional questions from the survey suggested incorporation of low impact development (LID) practices into a stormwater management plan was seen as a favorable tool by about 60 percent of respondents.*

Economics of Stormwater Management (Chapter 6)

J. Wesley Burnett[1] and Christopher Mothorpe[1]

Like all human-developed infrastructure, ponds require maintenance and monitoring throughout their life-cycle to ensure ongoing function and environmental effectiveness. The costs of maintaining ponds often ultimately fall on local, residential homeowners associations (HOAs). However, HOAs may be unaware of their responsibilities or lack knowledge as to whether their ponds are properly serving their designed functions of flood protection and mitigating harmful runoff. Uncertainty is compounded by deficient maintenance budgets.

PUBLIC GOODS: From an economic perspective, ponds are "impure" public goods, meaning they provide both public and private benefits.

PRIVATE PROVISIONS: When public goods are privatized, there can be an under-provision

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of funds by property owners or HOAs so ponds are maintained at an inefficient level.

INCENTIVES: Some research suggests that governments can combine both credible punishments and incentives such as subsidies, grants, rebates, and installation financing to improve maintenance activities.

EDUCATION: Because the public is largely uneducated about stormwater maintenance practices and costs, economists advocate for inclusion of formal educational programs.

COSTS: Various studies from throughout the U.S. found annual maintenance costs are between 2 and 8 percent of original construction costs, depending on pond size. Operating and maintenance costs fall as pond size increases. (**Fig. ES.8**)

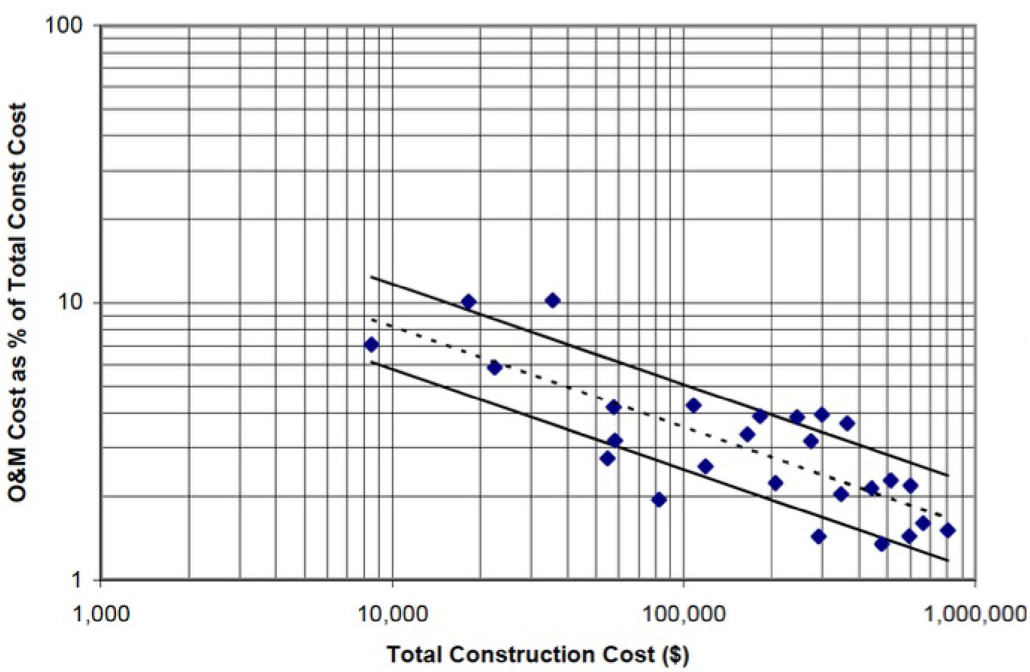
LOCAL COSTS: From a survey of 58 stormwater practitioners from S.C., we estimated the following costs:

1. Costs of new pond construction are between $17,000 and $33,000 per acre.

2. Annual maintenance costs per pond are between $230 and $760 per year.

3. Therefore, for a 0.54 acre pond (average size of urban ponds in coastal S.C.) annual maintenance is between 1 and 8 percent of the initial construction costs.

Figure ES.8 *Predicted annual life-cycle maintenance costs taken from the available scientific literature, as a function of total construction costs in 2005 U.S. dollars for ponds across the country.*



Notes: *Diamond shaped points represent empirical estimates from the literature. The dashed line represents a line of best fit through the points. The two solid lines represent the 67% confidence interval for the estimates.* Source: Weiss et al. (2005, p. 31).

Communication Strategy for Improved Pond Awareness (Chapter 7)

Katie A. Callahan[1], Amy E. Scaroni[2], C. Guinn Wallover[2], Melinda Weathers[3], Alex Neal[4]

The success of stormwater ponds as BMPs to manage runoff, protect downstream water quality, and comply with regulations relies on several factors: recognition of ownership; awareness of the pond's purpose; knowledge of pond function and maintenance needs; and responsible care of surrounding landscapes. These elements must factor into outreach messaging if it is to resonate with target audiences (**Fig. ES.9**) and ultimately protect S.C.'s vital coastal water resources. Messages should recognize the multiple concerns, perspectives, and involvement of multiple audiences.

SENSE OF OWNERSHIP: Messages should help all residents feel a sense of ownership of the stormwater pond and responsibility for its maintenance and performance.

POND PURPOSE AND FUNCTION: Communicate the pathways of stormwater; how it passes over impervious services, collects contaminants, and ultimately is collected within the engineered pond.

COMPREHENSIVE GUIDANCE AND SOLUTIONS: Messages should recognize the complexity of stormwater pond management and offer specific management strategies for stormwater ponds. Messages should be proactive and include actionable behaviors.

INITIATE MESSAGING EARLY: Messages should target audiences that influence stormwater pond design and maintenance as early in the process as possible. Messages should also include positive neighborhood feedback to challenge social norms.

HEALTHY PONDS, HEALTHY COMMUNITIES: Messages should stress that stormwater pond maintenance will benefit health of residents, wildlife, the pond ecosystem, and recreational waters.

TRUSTED INFORMATION SOURCES: Messages should come from trusted sources and outreach should capitalize on electronic modes of communication.

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Stormwater Pond Audiences and Perceptions

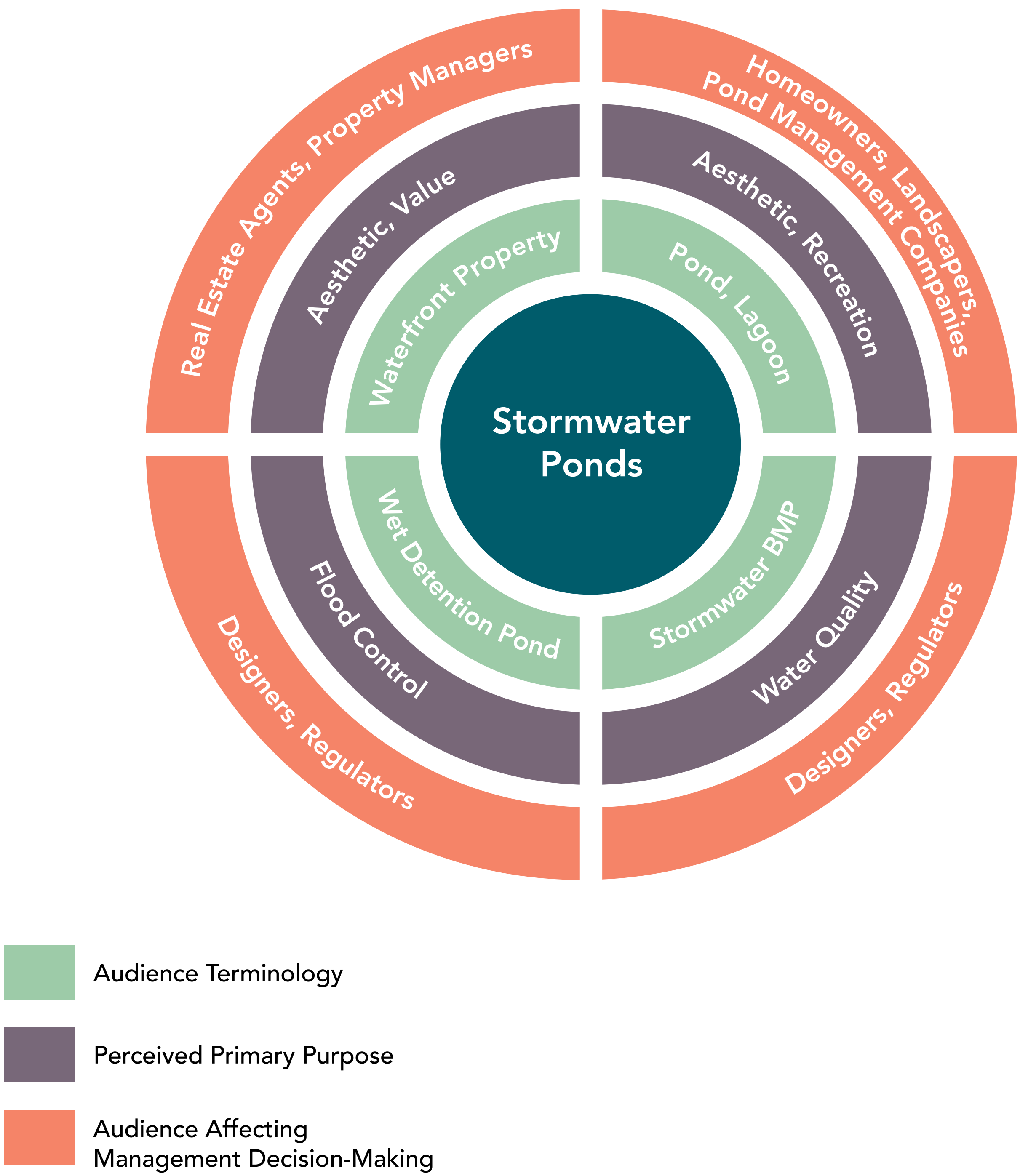

Figure ES.9 *Multiple audiences and perceptions affect stormwater pond management and messaging.*

CONCLUSION

The S.C. Stormwater Ponds Research and Management Collaborative seeks to ecologically characterize coastal stormwater ponds, understand their functionality and durability, and ultimately develop new and possibly innovative engineering and construction practices. The goal is to ensure that stormwater ponds, both existing and newly constructed, will function without concerns about possible ecological impacts or economic costs associated with their management and maintenance under current and future weather and climate patterns. While prevalent, very little information exists about their effectiveness, long-term functionality, and potential impacts on the adjoining ecosystem. A quantitative assessment of what hydrologic and water quality services ponds provide, and which management practices may maximize these services, is therefore essential to assist coastal communities in better managing their stormwater to preserve vital water quality and aquatic resources.

Faculty and students from many of the Consortium's member institutions and its own staff are participating in the Collaborative. Bringing together water quality specialists, engineers and ecologists, hydrologists and coastal processes specialists, biologists, public health and marine biomedical professionals, and economists and social scientists will enable us to holistically address these issues. And the results of this state-of-knowledge examination will provide a firm foundation for a large-scale research and development effort which will have economic, environmental, and public health benefits for the state and the Southeast region as it addresses the challenges of continued development, ecosystem and public health, and changes in climate and weather.